RESEARCH DIGEST

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IMPLEMENTATION OF UNKNOWN PILE LENGTH RESEARCH

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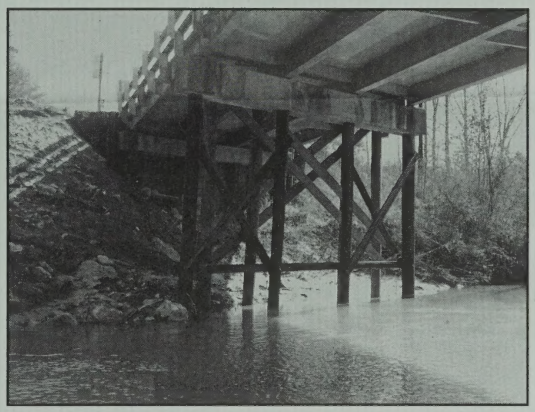
As a result of a field demonstration in March 1991, Division of Highways operational and preconstruction staffs recognized the potential for using dispersive stress waves in the determination of the in-place length of timber pilings. It was also apparent that this technique would also be helpful in assessing load bearing capacity and pile embedment conditions. Since the Division of Highways had maintenance responsibility for approximately 6500 bridges which are wholly or partially supported by timber pilings, the integration of this technique into bridge scour analysis procedures was believed to be invaluable. Accordingly, the Division of Highways awarded a two year contract research project to North Carolina State University in July 1991 to develop a non-destructive testing procedure for determining the length of installed timber pilings based on dispersive wave propagation theory. This study was performed under the direction of Dr. Robert A. Douglas.

The ensuing research project successfully demonstrated that bending waves can be manually introduced into a timber pile by moderate physical impact and that these bending waves can be accurately monitored during their propagation and return along the pile. A signal processing methodology was derived from classical Fourier Mathematical Transformation theory. This methodology was described as the Short Kernel Method and it could be utilized by trained engineers to determine the velocities of the spectral components of dispersive bending waves to calculate the in-situ lengths of timber piles. Following the derivation of the Short Kernel Method, it was subjected to comparative analysis on twenty six different timber pilings in actual filed conditions where the pile lengths were either known from available records or measured upon extraction from the ground. The percentage difference between the computed values and the actual values ranged from -11.8% (too short) to +8.7% (too long). These results were of sufficient accuracy such that a subsequent decision was made to form a core training group comprised to representatives from the Soils & Foundations Section of Design Services Unit, the Hydraulics Unit, and the Bridge Maintenance Unit. This group was given special instruction by Dr. J. Darrin Holt who had previously served as a graduate research assistant under Dr. Douglas.

From August 1993 through December 1993, Dr. Holt instructed this group during regular weekly sessions in the fundamental principles of wave mechanics and propagation theory and in the procedures for operating the signal conditioning testing apparatus. The Bridge Maintenance Unit purchased the required testing apparatus and made this equipment available to the group throughout this interval. The apparatus consisted of a Nicolet oscilloscope, direct current power supplies, accelerometers, and coaxial cabling. The instruction focused on the development of basic understandings of simplified wave motion in solid cylinders, principles related to dispersion of bending waves in solid media, and digital signal processing techniques involving the



Fourier Mathematical Transformation and the Short Kernel Method. Step-by-step instruction was provided describing the exact analytical sequence for determining pile length. The group was also familiarized in the use of the PILE personal computer program, software developed to fully describe the Short Kernel Method. This software was compiled in ZBASIC language for graphical layout and in FORTRAN77 language for numerical computation.

Since this successful period of instruction, the Division of Highways has incorporated the use of the wave propagation and analysis techniques from the PILE program into its routine bridge scour procedures. This has involved staff from the Bridge Maintenance Unit, the Soils & Foundations Section of the Design Services Unit, and the Hydraulics Unit. Specific substructure conditions are analyzed and reviewed and, as appropriate, recommendations are submitted to the Bridge Scour Committee for approval. During the interval from January 1994 through July 1995, field data collection for unknown pile lengths was scheduled by Bridge Maintenance Unit personnel for approximately twenty five different structures. Of these twenty five structures, analytical studies for embedded pile length have been performed by the Soils & Foundations Section for approximately sixteen structures. With the concurrence of the Hydraulics Unit, the Soils & Foundations Section has presented recommendations to the Bridge Scour Committee for corrective action for three specific locations. These recommendations have included the use of rip rap protection, the installation of crutch bents, and the continuing evaluation of scour critical elevations. These structures have been located in Halifax and Catawba Counties. The Hydraulics Unit and the Soils & Foundations Section have also recommended the use of supplementary penetration tests for field investigations conducted during 1995 and 1996 to confirm the accuracy of the analytical results. This supplemental practice will include the driving of one half inch diameter steel rods adjacent to each exterior pile for each bridge bent that will be investigated in the field. A database will be compiled to analyze the results. Thus, the results of the contract research project and the supportive logistical and data collection efforts by the Division of Highways have been put to very effective and worthwhile use. The supporting staff is also committed to improving the utilization and results from the PILE Program as sufficient data is collected.

Specific inquiries concerning the use of pile length determination system may be directed to Mr. J. D. Lee, P.E, State Bridge Maintenance Engineer, at telephone (919) 733-4362. Research report copies covering the various contract research studies may be obtained from Ms. Portia McLean, Research and Development Unit, telephone 919-715-2461, FAX (919) 715-0137.

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